University of Moratuwa, Sri Lanka
B. Sc. Engineering Degree Course
Final Part III Examination 2000/01

UEE403 - HIGH VOLTAGE ENGINEERING

0900 - 1200 hrs 16 September 2002

Answer **F I V E** Questions Only.

Question 1 carries 28 marks and all other Questions carry 18 marks each.

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1 (a) Describe very briefly with the aid of suitable diagrams the mechanism of the lightning stroke generation. [3 marks]

(b) Describe, with respect to surges originating in an overhead line, the effect of connecting the overhead line to the terminal equipment via a short length of cable. [3 marks]

(c) Describe the use of sphere gaps in high voltage measurements. [3 marks]

(d) Derive an expression for the deflecting torque of an electrostatic voltmeter used to measure high voltages. [3 marks]

(e) Derive an expression for spark breakdown in the Townsend breakdown process, stating any assumptions made. [3 marks]

(f) From first principles, show that surges can be represented by a combination of travelling waves. [3 marks]

(g) Assuming standard expressions for inductance and capacitance of a transmission line, obtain an expression for the velocity of propagation of surges. State also what the symbols in the equation represent. [4 marks]

(h) With suitable diagrams, explain how a resistive potential divider, connected at the output of an impulse generator, can be matched to the cable connecting it to an oscilloscope. [3 marks]

(i) Explain briefly why the principles used in the generation of high voltages for testing purposes cannot be used in generation of high voltage for power transmission. [3 marks]

2 (a) By deriving from first principles, show that the electric stress in a single core cable is not uniform. [3 marks]

(b) A single phase cable for a 3-phase 66 kV system, is to be designed using 3 insulating materials A, B, and C with peak critical breakdown stresses of 180 kV/cm, 200 kV/cm and 250 kV/cm and corresponding relative permittivities of 4.4, 3.2 and 2.8 respectively. If the conductor radius is 10 mm, determine the order and thickness of the insulation for optimum dimensions of the cable. Take a safety factor as 2 in the design. [8 marks]

(c) By considering a particular instant of time, sketch the field pattern in a three core belted type cable. [4 marks]

(d) Derive the basic equations that you used in sketching the above field pattern [3 marks]

3 (a) The simplified equivalent circuit of an impulse generator is shown in figure Q3, with the capacitor C_1 being initially charged. Derive approximate expressions for the voltage efficiency η of the impulse generator, and the charging time constant τ_c and the discharging time constant τ_d. [5 marks]

(b) Obtain also expressions for the wavefront time (based on 30% to 90%) and the wavetail time in terms of τ_c, τ_d and η. [5 marks]

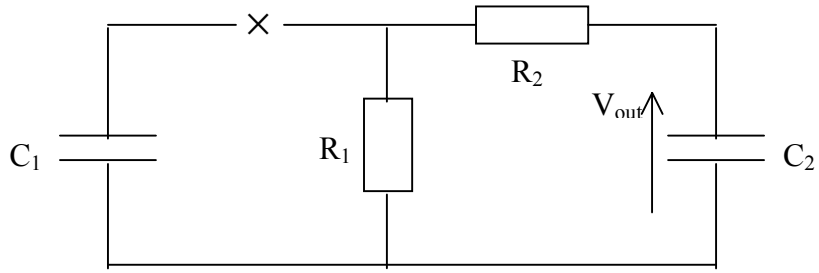

Figure Q3

(c) It is desired to design a 6-stage impulse generator to have an output voltage of 1000 kV of standard IEC waveform, and to have an output energy of 50 kJ. Making reasonable judgements, determine the main components of the multistage impulse generator. [6 marks]

(d) Draw the complete circuit indicating values for each component. [2 marks]

4 (a)

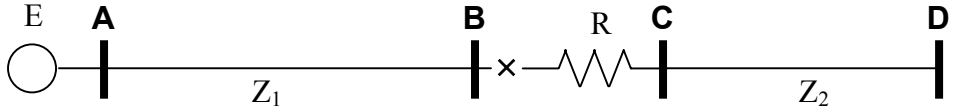

Figure Q4

A constant voltage source of magnitude E has energised the line AB initially with the switch at B open. If the switch is closed at time t = 0, determine expressions for the first surges that would set off on BA and CD. [4 marks]

(b) If E = 240 kV, Z_1= 500 Ω, Z_2= 400 Ω, and R = 300 Ω, travel time of CD is 100 μs, D is on open circuit and A is too far from B for reflections to be considered during the period of interest, determine and sketch the voltages at B and C for the first 250 μs after the switch is closed at time t = 0. [8 marks]

(c) Briefly explain the significance of the use of a resistor R in a circuit breaker. [2 marks]

(d) Briefly explain the use of the Bergeron Method of surge analysis for a non-linear system. [4 marks]

5 (a) Describe the Schering Bridge method of obtaining the capacitance and loss tangent of a lossy dielectric and write down the balance condition. [4 marks]

(b) An overhead line AB (Z_o = 450 Ω) feeds two other lines BC (overhead line, Z_o = 450 Ω) and BD (cable, Z_o = 50 Ω). If a step surge of magnitude 100 kV originates on AB and travels towards B, obtain the magnitudes of the first voltage surges and current surges travelling on BC and BD. [8 marks]

(c) Two overhead lines AB (Z_o=450 Ω, 60 km) and BC (Z_o=350 Ω, 30 km) are connected to a load (Z_o=1650 Ω). A triangular wave of vertical front of 100 kV and duration 250 μs originates in the overhead line AB and travels towards the junction B. Draw the Bewley Lattice diagram and obtain the voltage at B for the first 300 μs after the original surge arrives at B. Neglect attenuation. [6 marks]

6 (a) Derive from first principles the expression $\frac{\Delta t}{x} = \frac{1}{B}\left[1 - \frac{e_0}{e}\right]$ $\mu s/m$ for the corona distortion as a surge travels along a transmission line. [6 marks]

(b) A surge with a magnitude of 160 kV has a linear rate of rise of 800 kV/μs. It originates in a transmission line with a surge impedance of 450 Ω and travels towards a terminal device (Z_0 = 2550Ω). It is protected by a lightning arrestor at a distance of 20 m from the device. If the arrestor flashover voltage is 210 kV, determine the time at which the arrestor operates and the maximum voltage to which the terminal equipment will rise.
[velocity of propagation: overhead line 3 x 10^8 m/s, cable 2 x 10^8 m/s] [12 marks]

7 (a) For a hexa-phase bridge convertor, sketch the typical waveforms of (i) voltage across a thyristor, (ii) the output d.c. voltage, (iii) current through a thyristor and the (iv) input line current on the a.c. system. [4 marks]

(b) Derive an expression for the mean value of the d.c. output voltage, when the line voltage on the secondary of the transformer is E, the delay angle is α and the commutation angle is γ . [4 marks]

(c) Derive an expression for the power factor of the convertor for a given delay angle α and commutation angle γ . [4 marks]

(d) Derive the necessary equations and sketch the per-unit convertor characteristics. [6 marks]